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High-Energy Liner Experiment (HEL-1)

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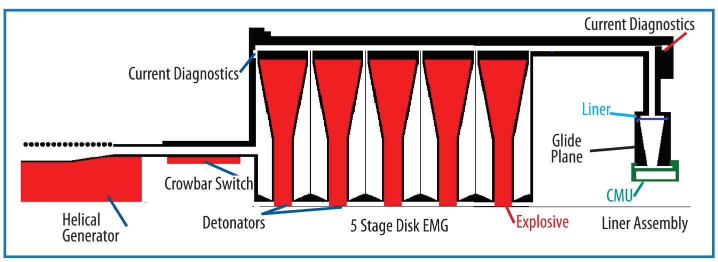
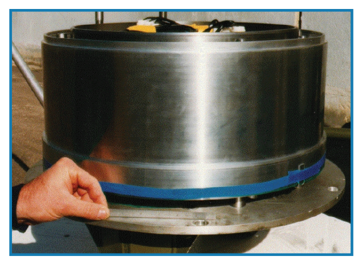
Project Description

Complementing the exploration of high performance liners at Pegasus (6-10 MA) and Atlas (15-25 MA) scale, a very High-Energy Liner implosion experiment (HEL-1) was conducted at 100 MA. The HEL-1 experiment was conducted in August 1996 by a team of scientists from Los Alamos National Laboratory (LANL) and the All Russian Scientific Research Institute of Experimental Physics (VNIIEF). The power supply for this experiment consisted of a disk explosive magnetic generator (DEMG) system delivering over 100 MA to an imploding liner experimental assembly. The DEMG consisted of five 1000 mm diameter disk generator elements, connected in series, with the seed current provided by a helical explosive generator. A preliminary test of this configuration, using a 5 nH static inductive load, produced 170 MA into a constant inductance load. Experiments reported by VNIIEF in the 1980s with this type of DEMG imploded copper and aluminum liners with masses up to 1200 grams. The aluminum HEL-1 liner was initially over 1600 grams.

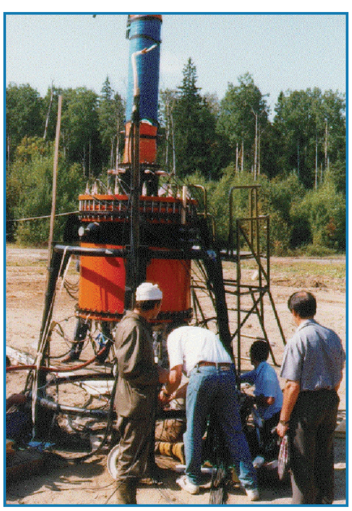
The objective of the experiment was to accelerate the aluminum liner to a kinetic energy of 20 MJ or greater and, through detailed diagnostics, determine the state of the liner when it arrived at the central measuring unit (CMU). The 100 MA current pulse produced by the DEMG imploded 1.6 kg, 4.0 mm thick aluminum alloy liner from an initial inner radius of 236 mm onto a target of radius 55 mm in a Z-pinch configuration. Both the end conductors (glide planes) and the target or central measurement unit contained an extensive array of diagnostics. Analysis of the experimental data from these diagnostics



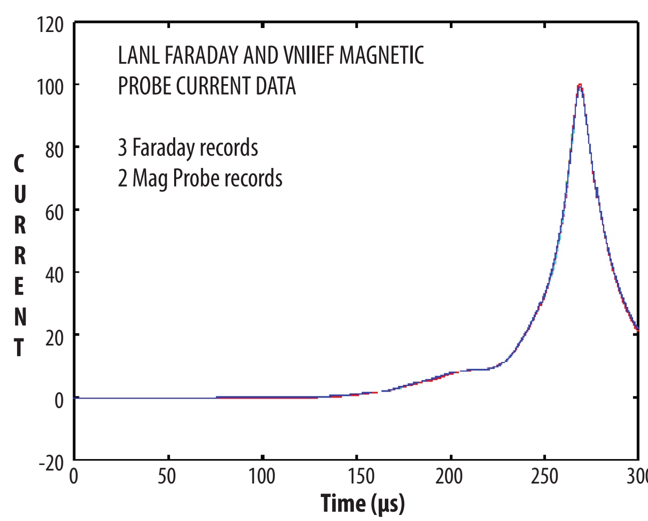
Disk Explosive Magnetic Generator system.



HEL-1, 1.6 kg liner.



HEL-1 experimental assembly.



The DEMG produced >100 MA current to implode the liner.

showed that the inner surface of the liner reached a velocity between 6.8 and 8.4 km/s, consistent with detailed numerical calculations of the experiment using Legacy integrated codes. Those same calculations indicated that the liner was still substantially solid at the time of target impact and had a total kinetic energy of about 20 MJ. In virtually every way, the performance of the power supply, the transmission line, and the liner dynamics results agreed with calculations, usually to within 5%.

Technical Purpose and Benefits

The NNSA mission includes the need to validate sophisticated computer models of complex implosions at large scale and high velocity. Such implosions involve large amounts of kinetic energy, high pressures, high strains, and rates-of-strain in situations where detailed diagnostics are not always available. The magnetically imploded cylindrical liner provides a flexible, controllable, diagnosable source of data against which to validate both physics models and integrated codes. The successful execution of the HEL-1 experiment demonstrated the technology needed to produce such high precision data for validation and the capability to use high-energy liners to produce other high energy density environments for validating advanced physics models. Representative future applications include the generation of high pressures (100's of GPa) over relatively large areas (100-1000 mm^2) for material studies, the production of plasmas at near solid density for the study of warm, dense matter, the generation of high magnetic fields (1000 T and greater) in relatively large volumes (10's mm^3) for basic studies of the magnetic properties of matter, and the compression of a magnetized fusion plasma in Magnetic-Target Fusion (MTF). These applications are feasible only if the high-energy power supplies are reliable, their performance is predictable, and the energy can be efficiently delivered to loads. The HEL-1 experiment demonstrated that such an experiment can be designed using existing components and models, and that the system will perform as designed.

ВНИИ

VNIIEF

Collaboration between Los Alamos National Laboratory (LANL), Los Alamos, NM, USA, and the Russian Federal Nuclear Center – All Russian Research Institute of Experimental Physics (RFNC-VNIIEF), Sarov, Russia

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